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NOTES ON SOME RESEARCHES AMONG THE DIATOMACEÆ.

BY K. M. CUNNINGHAM.

(*Read November 17th*, 1893.)

By a peculiar trend of events my attention had recently been called to the question of the plant or animal nature of the diatoms. This question had hitherto been of little interest to me, very nearly all of my interest having been directed merely to an accumulation of specimens of fossil or recent deposits and the study of their distribution. But certain favorable opportunities have enabled me recently to devote some attention to the study of living diatoms. With this object in view I have prepared, and, after due study of the same, I send herewith the series of slides illustrating this paper as a donation to the Society.

It may be of historic interest to recall the fact that in the "Smithsonian Contributions to Knowledge" there is a publication, bearing the date of 1850, and entitled "Microscopical Observations made by J. W. Bailey, of West Point, N. Y., during a tour through the States of South Carolina, Georgia, and Florida," in which work were listed and tabulated all infusorial and other microscopic forms of life encountered in his travels through the said territory, including the diatoms and the desmids, with figures of the new species found by himself. Since the year 1878,

when I became aware of the existence of the publication, its subject has lain as a dream in my mind. Years after, when I had become quite familiar with the diatoms of both the South and the North, I recalled that in his tabulation from all sources he had listed about ninety-four species, including both marine and fresh-water, and never exceeding more than twenty-five species from a given locality. It has also been a matter of curious interest to me as to the methods of preparation for study in vogue in or about 1850. In the present day, as proved by my slides, I have been able to get eighty species in a single mount from Mobile Bay marine muds, and nearly seventy-five species from the brackish material from the shore of Mobile Bay—the same material as apparently examined by him from Mobile Bay. In alluding to this, I do so with full respect for the eminence of the most prominent investigator, in his day, of the diatoms of North America, and not with any desire to detract from the honor of his laborious researches; but the thought calls up the question as to whether the methods of to-day are in advance of those of nearly a half-century ago. In the preparation of this paper I could not well omit the name of Prof. J. W. Bailey, as its interest turns largely upon a diatom described and figured by himself from material derived from Mobile Bay, and shown in the plates to his work referred to above; and likewise shown in Wolle's "Diatomaceæ of North America."

The opening during the present summer of a resort on Mobile Bay, known locally as Monroe Park, by the Electric Railway Company, enabled me to visit a strip of the shore of Mobile Bay a few miles south of the city. While there, and looking around for something of interest microscopically, I came upon a stratum of lignite exposed on the beach at low tide. I repeated my visits to this place to study it geologically. With a desire to trace its extension, I made short excursions somewhat further down the shore line from the Park, especially on occasions when the tide was out in the evening. In this area the bay bottom was covered, so far as the surface was free from the tide, with a species of a moss-like water plant, which condition induced me to test whether this moss-like growth would prove a source of diatoms. I therefore gathered a portion of a plant, and by pressure forced the fluid to fall on a spectacle glass used for such tests in the

field. On drying the glass I examined it, and was rewarded by finding an abundance of diatoms, including a species which I had nearly despaired of ever finding or seeing. This proved to be Bailey's *Amphiprora ornata*, as figured in his "Microscopical Observations, etc., in 1850." During all the previous years of my diatom researches I had desired to find *Amphiprora* of any kind whatever, but apparently in vain. Having my "treasure trove," I secured one full plant with its complement of mud, and it is from this, and a second supply of the clean plants, that I have prepared the series of six slides typical of the original material that Bailey must certainly have examined, as he referred to material often gathered from bogs or on shores where the diatom ooze abounded.

On the very same evening that I secured this moist water plant I spent some hours in its examination, applying myself more particularly to the character of the motion of the living diatoms. It took me but a moment to find on the slide specimens of living *Amphiprora* and *Navicula*. Confining my attention closely to the appearance and structure of *Amphiprora ornata*, I was enabled to observe that, if a bacterium drifted toward it and made contact, it would be held as a prisoner in the full power of the protoplasm covering the diatom externally. As is well known through mounted specimens, as well as figures, *Amphiprora* has delicate, hyaline, and rather broad alate lateral processes. Bacteria and rotifers, once in contact with the peripheral edges of the alæ of the *Amphiprora*, are kept in a constant state of alternate or reciprocal motion from either diametrical extremity. That is to say, the bacterium or other organism is rapidly transported from the middle constriction to one or other of the extremities of the diatom, all the way, or part of the way, in an alternating manner; when it may, after an interval of detention, be rejected by what appears to be a voluntary impulse of the *Amphiprora* itself. Having seen this phenomenon, I at once became aware of its importance in any discussion involving the plant or animal nature of the diatom, and more particularly as all my previous acquaintance with the Diatomaceæ had permitted me to remain content with the generally accepted opinion that the diatom was "a lowly unicellular plant."

This accidental discovery of the motility of the protoplasmic covering of the *Amphiprora* induced me to see what was already of record in relation to the cause of the directive motion of many genera of the Diatomaceæ, but more particularly the Naviculæ. I forthwith consulted all the available references to the life history of the Diatomaceæ within reach. Neither the "Encyclopædia Britannica," latest (ninth) edition, "The Columbian Cyclopædia" (1892), "Micrographic Dictionary" (1856), "Carpenter on the Microscope" (1856), Rev. Francis Wolle's "Diatomaceæ of North America" (1890), "Generalities, on the Diatomaceæ," of Count Abbé Francesco Castracane (1884), nor the address of ex-President Charles F. Cox before this Society, entitled "What is a Diatom?" and published in full in the JOURNAL (January, 1892), contained the slightest reference to, or a suggestion of the phenomena partially described in the preceding introduction, but most or all of the authorities confined their notice to the distinct and evident motion of translation of the diatom frustule in a simple direct or retrograde motion. The mystery of its motion was left involved in hypotheses, and no satisfactory solution was offered by the various observers. That any diatom had a dual or a subsidiary motion was everywhere regarded in the negative or not entertained at all. The *Amphiprora*, which clearly exhibits this dual power, is not mentioned at all. The fact that *Amphiprora* has some of the attributes of protozoan life, rather than that of plant life, had been hitherto overlooked, or at least seems to not have been specifically alluded to, especially as appears in Wolle's "Diatomaceæ of North America," which presumably should give the highest reach of experimental research obtaining on this subject to the year 1890. In the opinions submitted therein the cause of the motion of diatoms remains a mere hypothesis requiring elucidation. And no authors so far have touched upon the subject of the dual or compound motion exhibited by *Amphiprora ornata* or any other species of *Amphiprora*.

After my initial experience related above, I made a second visit to the bay shore, and carried along a collecting bottle, into which, from a new supply of the peculiar moss-like water plant, I expressed as much fluid from it as I deemed necessary, and at night proceeded to study it *de novo*. By the most delicate manipulation known to me I freed the material from sand, and by repeated

washings in water and by a special form of concentration I secured a dip to examine on an uncovered slide. For a period of three hours I watched the various living and moving diatoms, noticing closely every condition presented by such as appeared, but seeking especially to keep in the field an *Amphiprora ornata*, which is one of the smallest of its genus, but sufficiently large to study clearly. The same phenomena were presented as in the first experiment, but with this variation: after observing a bacterium that had touched the edge of the ala on the left side, it was oscillated a few times alternately, and was then transferred along the edge of the ala to the constriction, and then continuously across the broad central portion of the frustule to the ala on the right side, always along the periphery, and on to the opposite extremity of the diatom, where it disappeared. Immediately after this a good-sized, motionless rotifer drifted into contact with the left ala and was rapidly rotated along the edge of the ala on the left side, and was then carried to the middle constriction, where it was retained some time, when it was rejected by the diatom. While the rotifer was being manipulated on the left side a bacterium was performing its oscillations on the right periphery, and what appeared to be a cluster of bacteria were held prisoners above and around the middle portion near the constriction of the alæ.

Another feature of interest attaching to the motion of *Amphiprora* is that in the event of its being capsized by striking some obstacle in its path of motion, if thrown on its narrowest edge—front view—it at once struggles to regain the position, which displays its side view, and then its motion continues direct and rapid. This action intimates an intelligence akin almost to that of a beetle on its back exerting itself to regain its natural position on its feet.

While shifting the field in order to observe some other indications of the life motions, I observed a simple, small *Navicula* having in contact at one of its sublanceolate ends a *Nitzschia closterium*—closely agreeing with Wolle's figure. The *Navicula* seemed to be rapidly driving the *Nitzschia*, in the manner that a violin bow is rapidly drawn by rising and falling strokes, or in a see-sawing motion, while the *Navicula* was quiescent. This produced the illusion of the source of motion being situated at the prow or apex of the *Navicula*. But a moment later the illusion

was explained by seeing another *Nitzschia closterium*, having attached to its exoplasmic layer foreign particles that were being rapidly transported around its entire periphery, from the right side around to the left, sometimes direct, sometimes alternating. At another time I saw a small rotifer held a prisoner by a small *Navicula*. At times the rotifer moved away a space equal to its diameter, but was drawn back each time into a fresh contact with the edge of the diatom, as if by some invisible force. While still in contact with the *Navicula*, it drifted or was drawn between the *Navicula* and an *Amphiprora* into a sort of cul-de-sac. I saw also that under this mysterious force it vibrated rapidly between the two diatoms—the rotifer, being inert, had not an independent power of motion to release itself from its captors. In the drop of water on the slide there were numerous and very active small *Naviculæ*, whose motions presented nothing of special interest, except possibly that they often came in contact with larger *Naviculæ* and passed by in contact with the protoplasmic sheath of the larger diatoms, and soon parted company with them, as their motion was swifter and not retarded by the sliding contact. This will suffice to record such observations as were derived from a painstaking study of material taken from the shore of Mobile Bay and examined within an interval of six hours.

Desiring to gather additional data bearing upon the behavior of the living diatom under the lens, I had, about a week previously, secured some fresh-water diatoms directly from a natural spring at the village of Whistler, Ala., five miles north of Mobile. On a visit to the same locality in March last I casually found a beautiful, clear spring flowing from a grassy, sloping hillside into a barrel sunk flush with the grassy surface of the adjacent ground. Selecting a small sample of the algæ through which the spring flowed away, I expressed the fluid therefrom on a spectacle glass, and examined it with a pocket lens. I was surprised to find the glass surface covered with a pure gathering of *Navicula viridis*, all united in fours, or what I would call "tetradelphia." I then collected in a bottle a portion of the material and took it to Mobile for examination as to the number and association of species. But too much extraneous matter prevented a suitable slide from being prepared, and the beautiful phenomenon of the spectacle glass could not be repeated. On a recent

visit to the same spring, in the early part of September, I took with me a one-ounce bottle with parallel sides and semi-cylindrical ends, which form was useful in the subsequent observations. Having in mind the subject of the motility of the brackish-water diatoms of Mobile Bay, I desired to pursue the subject further with a distinctly fresh-water variety of diatoms. The material expressed from the algæ of this spring I studied for five consecutive days.

On the evening of the day that I secured the Whistler material I prepared a portion for examination, by repeated washings, settlings, and changes of water, and then placed a drop on a slide, when I found an abundance of living *Navicula viridis*—single large individuals, and shorter ones grouped in fours and adherent to each other. The first fact verified was that during the interval between March and September the diatoms were still largely represented by the fourfold combination seen on my first visit to the spring in March.

The following is a résumé of what I observed during a close study of the living material. On the first night of my study I sought to detect, if possible, the presence of the protoplasmic mantle or sheath as demonstrated and observed by Cornelius Onderdonk, and recounted by him in *The Microscope* (1890). Having the living diatoms at hand, I made a concentration and removed as much water as possible, in order not to weaken the dye. I also had convenient a bottle of aniline violet ink, to use in the attempt to differentiate the protoplasmic mantle as indicated by Onderdonk. On adding a few drops of the aniline dye to the living frustules, I quickly placed a drop of the diatoms on the slide and covered the same with a three-quarter inch cover glass. My surprise was great when I observed that the diatoms had been instantly killed by the liquid. All that portion of the field not occupied by the diatoms or débris gave no color indication. After a fruitless search for any indication of an evident protoplasmic layer, I came to the conclusion that it was of such exceeding tenuity that it did not extend sufficiently far from the silicious frustule to indicate its presence at all. But the dye took at once on the diatoms, and on every other particle of matter, vegetable or otherwise. The only inference I drew from this experiment was that the aniline paralyzed instantaneously the

life function of whatever protoplasmic coating that might have previously given rise to the power of locomotion in the frustules.

It then occurred to me to test the effect of the aniline as a means of differentiating the diatoms, the strong and robust, as well as the hyaline forms, which are sometimes nearly lost to view in balsam mounts. For this purpose I allowed a liberal amount of the material to remain in a concentrated solution of aniline for a period of five hours, when I washed them repeatedly in changes of water until no more color was evident in the fluid removed. The result of this staining has furnished me with a wide range of interesting data, fairly recorded in a mount forming a part of the whole series of slides made to accompany these notes. Notably among the phenomena presented may be mentioned that on the slide may be seen numerous large, solitary specimens of *Navicula viridis*, and specimens of a smaller size of the same grouped mostly in fours, adherent together, and others by twos alone. In addition to these there are many specimens of *Eunotia*, *Fragillaria*, *Navicula radiosa*, and other smaller forms, all showing an elegant amethystine color by daylight and a reddish violet by student's-lamp light, and demonstrating that the stain had taken satisfactorily. This staining with aniline violet differentiated certain structures that would not have been modified in balsam mounts. The living diatoms, dried on the slide and covered with balsam, present the endochrome in a uniform layer of color, filling the whole internal part of the frustule, in the various shades of green, olive green, or brownish hues. Whereas, with the aniline stain, the endoplasm has been rent asunder and driven to the side walls of the frustule, and is there densely stained and banked up against the separating walls of the quadruple-grouped diatoms, there being a distinct hyaline or clear line of silex separating the frustules where in contact, thus differentiating separately the collapsed endoplasm of each separate frustule. This action of the aniline on the larger frustules was identical for all. But on the smaller forms the endochrome is merely indicated by two central patches highly stained, with a clear bisecting line of silica separating the two masses of endochrome, the sides of the frustules also showing hyaline borders internally. I said above that there was no appreciable thickness of the layer of exoplasm on the frustules, yet it is evident, by the

frustules taking the stain in such a dense and beautiful manner, that there must have been an infinitely thin layer of protoplasm, which appropriated the dye. My reason for this conception is, that in the two slides of the Montgomery, Ala., fossil fresh-water earth, which also form a part of the series of slides, the silica, no longer having any plasmic coating, refused to take the aniline dye, except in a manner to be referred to further on, the plain surfaces separating the lines of ribs being almost devoid of any show of stain. The above is about all of interest that I could determine as to the effect of an aniline dye on the living frustules.

The bottles containing the living diatoms from Whistler, as well as the fresh brackish-water material from Mobile Bay, were allowed to remain over-night on the mantel near the window. On the next morning I observed the contents of the two bottles with a band lens, and noted that hundreds of the Whistler diatoms had left the sediment and algæ at the bottom, and were travelling around near the line of the surface of the water in the bottle in preference to any other part of the sides. At this moment I recalled the common statement that diatoms, as well as desmids, will congregate at the lighted side of the vessel holding the mud with which they are mingled. To verify this I successfully used the following expedient: Thrusting the bottle previously described tightly down into a parlor match-box, I cut a hole in the paper of the box, a quarter of an inch in diameter, at a point about the middle height of the fluid, and on the reverse side I cut a similar hole, taking care not to detach the pieces of paper, so that they might be opened and shut as little windows, so as to admit transmitted light through the fluid on subsequent examinations. Having done this, I excluded all light from every part of the bottle, except from the central quarter of an inch hole. When this was done I exposed the bottle to the diffused light of the day, toward the south, and at convenient intervals during the daylight, for the balance of the day, I observed such changes as went on at the orifice admitting daylight.

The first phenomenon of interest, after about one hour's exposure, at about 9:30 A.M., was that the diatoms had already congregated at the spot of clear glass in fair numbers and were travelling across the field in all directions, with an easy, steady, direct motion. There were also groups of the "tetradelphia"

N. viridis, and the single larger *N. viridis* was seen. But the most unexpected thing noted was that seven Cyclops and Cypris, and the young of the former, had gathered at the light spot. In a moment the Cyclops scattered, but the Cypris kept on its lively feeding and remained constantly within the spot admitting the light. At other intervals during the day the Cyclops could always be seen playing around or darting across the light spot, and early in the day a few desmids appeared attached to little strands of algæ, and also a few large desmids—*Micrasterias rotata* and *Closterium moniliforme.*

At a time when the diatoms were noted as being quite abundant, I arranged the microscope by bringing the tube to a horizontal position, and placed the bottle upright between the thin metal stage and the substage. I then was enabled to observe the travelling motion of all the diatoms congregated within the radius of the quarter of an inch circular opening admitting the light directly through the centre of the liquid. A Beck & Smith half-inch lens gave a sufficient magnification, of, say, two hundred diameters, enabling me to view all of the diatoms, large or small, while in active motion. This method of examination has the advantage that the diatom is in actual contact with, and is adherent to, a smooth glass surface, and, as its movement progresses in a straight line for the whole distance of a quarter of an inch, the rate of movement can be timed by a watch. As this was relatively slow, it will be needless to state how many seconds were consumed in traversing the width of the opening. And as there were quite a number simultaneously crossing, there seemed to be no interruption to a continuous direct motion, as would happen when a slide is examined in a horizontal position and the field littered with particles of débris. When such is the case the direct motion is usually interrupted. An obstacle intercepting the path of the diatom causes it to reverse its propelling power, whatever that may be. But in the bottle there was no débris adhering to the sides, and the only obstacles to be encountered were other diatoms travelling at will in the general field. The desmids were never adherent to the glass, for if the bottle was held in the hand on any occasion they were always in a tremulous state, chiefly attached to minute threads of algæ, while the diatoms kept up a constant motion, always in contact

with the glass, while being examined with a moderately high-power hand lens.

This movement of the diatoms in contact with the smooth interior surface of the glass bottle will, I think, not yield to any other interpretation, except that the gelatinous character of the enveloping protoplasm permitted them to adhere safely to the glass without impeding their motion at pleasure ; and this is probably why there was little or no evidence of the jerky or retrograde motion often seen in a restricted field, as would appear under a one-sixth lens.

The facts developed here, and in the preceding account of the motility of *Amphiprora ornata*, I propose to utilize in the closing portion of these notes, when I will present my argument in favor of the plea that the diatom has as much right to be regarded as a protozoan as any of the other already acknowledged rhizopods. I return for the moment to note additional studies of the character of the motion of the large *N. viridis*. While contemplating the movements of a large specimen, I kept the diatom constantly in the field to test even a suspicion of any sheath or protoplasm covering. Noting very closely its perimeter, I was able to distinctly make out that the diatom was surrounded by a barely perceptible aureole, its outline being indicated by a row of three or four minute particles of débris—not bacteria. These remained continually at a permanent line close to one edge of the frustule, leaving a hyaline space separating them from actual contact with what would be regarded as the silicious edge of the frustule. While still keeping my attention fixed steadily on this line of minute débris, additional particles were gathered and took their position in line with the others. But for this phenomenon it would have been practically impossible to differentiate the extension of the gelatinous and pellucid covering from the surrounding water.

On another occasion I watched the action of drifting bacteria and other particles passed during the transit of the diatom. These were constantly drifting by, either above or under the frustule. Eventually the progress of the diatom was stopped for a few moments by collision with a mat of débris, when a large, motionless, gelatinous globule was arrested at its free extremity. At the moment I recognized that the globule was under and in

contact with the diatom, and about half-way freed from its end. Now, while the diatom was at rest, the globule, without any motion of its own, was transported back to a point under the central nodule of the diatom. After resting there a moment it was carried back to the free end of the diatom. Meanwhile the diatom freed itself from the obstruction, and the globule was liberated, and I then again saw that the globule was inert and incapable of motion of its own. Therefore it is reasonable to suppose that its motion was due to a propelling influence exerted over it by the exoplasm of the *Navicula viridis*.

With regard to the momentum of the diatom in motion, I saw a rapid traveller, a small *Navicula radiosa*, forge along and strike a large, quiet *N. viridis* about the middle, with such an impetus as to throw the *N. viridis* through an arc of more than forty-five degrees to the left of the point of impact It immediately regressed after the shock. The mathematical physicist could tell the nature of the impact—as impact is a resultant of weight and velocity, and motion is the opposite of inertia, one indicates life and action, the other inability to change position without some extraneous force.

Still drawing upon my study of the Whistler fresh-water gathering, I examined closely the behavior of the "tetradelphia" groups of Naviculæ. I observed that the quadruple brotherhood of so-called single cells could turn around in their own length, that they could also travel in straight lines, and that if capsized or thrown on their "beam ends" they struggled to bring themselves to the normal position of bodies swimming horizontally. While they were struggling to regain the plane of flotation I was enabled to study them in every aspect. In these frustules the characteristic endoplasm, endochrome, oil globules, vacuoles, etc., were clearly seen, more particularly through the cingula, or connecting band, as this is less lined than the frustular faces. This combination of four frustules would seem to suggest that the directive force of the quadruple frustules is controlled largely by the two external frustules, and for the four to move in a direct line the protoplasmic, propelling force (?) must be synchronous in all four; and when it is not so, or when the quadruple frustules are moving in a circle of their own length, the rapid, undulatory vibrations of the protoplasmic sheath of the two

outer frustules must certainly operate inversely to each other, or are not, at least, synchronous and impulsing in the same direction. This is merely suggested as an hypothesis of cause of motion.

As expanding further the subject of motion in the diatom, I will offer another phase that may have a useful bearing on certain of such hypotheses long in print and subject to revision. At another time, while seeking clues to the presence of the protoplasmic covering, I followed a large *Navicula viridis* in its movements through the water, as seen in the field of the microscope, the slide being uncovered. In the wake of the retreating end of the diatom there appeared to be a form of attractive suction over minute particles along its line of transit. A train of minute particles lagged along after the passage of the diatom, at a distance to the rear of about the width of the diatom, until the attracting power had ceased to act, when they would become still. The particles were drawn in semicircular arcs from either side of the axial line of the diatom's passing range, the axial line being tangential to the opposing arcs of motion of the particles following in the wake of the diatom. It would have been impossible for this movement of particles to have taken place if the motion of the diatom was caused by the expulsion, at any time, of infinitesimal jets of water. Likewise it offers an insuperable objection to the theory of motion accredited to Prof. Hamilton L. Smith and quoted from Wolle's "Diatomaceæ of North America": "that the motion of the Naviculæ is due to injection and expulsion of water, and that those currents are caused by different tension of the membranous sac in the two halves of the frustule," etc. Wolle also quotes Cornelius Onderdonk as ascribing the movements of diatoms to "a thin fluid mass in rhythmical motion," which Onderdonk had elsewhere proved to his own mind by experimental dyeing tests: "The fluid rhythmical mass covered the surface of the diatoms." I looked up the original communication of Onderdonk and read it. While his experiments were very interesting, he had made no reference whatever to the power of the protoplasmic layer to capture and tenaciously hold and transport, at its own volition, appreciable masses of living particles.

It may not be inappropriate to introduce herein a transcript of

Rev. W. Smith's views in regard to the motion of diatoms, quoted in Carpenter, edition of 1856: "Among the hundreds of species which I have examined in every stage of growth and phase of movement, aided by glasses which have never been surpassed for clearness and definition, I have never been able to detect any semblance of a motile organ, nor have I, by coloring the fluid by carmine or indigo, been able to detect in the colored particles surrounding the diatom those rotary movements which indicate in the various species of animalcules the presence of cilia" ("Synopsis of British Diatomaceæ," Introduction, p. xxiv.). This quotation would also seem to indicate that the Rev. W. Smith was not acquainted with the peripheral motion of the protoplasmic layer of *Amphiprora*, for if he had been acquainted with this he would have had to modify the above opinion and substitute a form of motility independent of any easily seen ciliary processes.

The theory which the sum total of my experience so far suggests is that the motion is probably caused by an infinitely rapid undulatory motion of the protoplasmic sheath, which I assume to exist, covering the diatom on all sides, which vibratory pulsations are too minute to be seen under any degree of magnification, and whose reactionary beats against the water cause the forward or retrograde movements at the instinctive will of the diatom.

Returning to the theory of propulsion advanced by Prof. H. L. Smith, and with all due regard for his long and signal experience in the study of living and other diatoms, I would respectfully call attention to some points calculated to weaken, or even vitiate, the claims of any expulsive action connected with a median diaphragm separating any two frustules that are united and in motion. The quadruple frustules are fairly quick in their progression. Were the hypothesis actually true for a single individual, we would, in the quadruple instance, have four frustules propelled by two exterior sides, and eight opposing prows, leaving the three central enclosed walls in "innocuous desuetude" until each frustule was allowed to shift for itself.

Before finally disposing of the question of motion of diatoms, I would like to advance two more points of interest bearing strongly upon the subject. In the brackish material containing *Amphiprora ornata* there were numerous specimens of *Navicula Smithii*. I gave some attention to one of these, and if the rela-

tively slow motion of a *N. viridis* can interest and hold the attention, this interesting form must in a higher degree give cause for admiration. Conceive a beautiful, strongly lined, golden-hued oval rushing through the water with a speed outdistancing all other forms that I have ever seen in motion. When this is seen it is almost impossible to disassociate the idea of a strongly pulsating life and animal energy from this little creature. To call it a "simple lowly plant" would be to treat it with a presumptive indignity. If one were permitted to speculate as to the character of its motion, the mind might conceive of vibratile pulsations as swift as the undulatory waves of light, or as the rapid alternations of the electric arc current in producing its light, if we take into consideration the diatom's minute size and its energetic progress through the water by the imagined pulsations of its invisible protoplasmic sheath.

Lastly, in relation to another character of motion—that of the *Bacillaria paradoxa*. When we have seen that the ribbon of conjugate frustules is brought to a straight line with terminal frustules, taking the order of "right dress," and that suddenly the end file leader darts off at a rapid stroke to the end of its neighbor, and that the others do the same in quick succession, until the whole line or group have passed each other, and then repeat the same movements in a retrograde manner, we have viewed a life movement of the most curious interest and truly paradoxical in its nature. If we carefully analyze the consequences of these successive phases of motion, we are forced to admit that each frustule has a sheath of a colloid or gelatinous character (somewhat like the coleoderma of De Brebisson) that allows the contiguous sides of each frustule to coalesce or anastomose and separate with equal facility. If this were not the case they could not live in collective communities. These facts substantiate, without staining or other experimental expedients, the truth that this diatom, and possibly all diatoms, are invested with a protoplasmic mantle imbued with life, and capable of being paralyzed or killed instantaneously by staining agents, and that this protoplasm has some of the characteristics of the protoplasm of the protozoa.

In the brackish material I witnessed a small *Amphora*, quiet and motionless, upon the flat surface of which a bacterium seemed to

be struggling to cross its body, being apparently held by the resistance offered by the protoplasmic layer of the *Amphora*. It is well known by those who have made a study of the simple *Bacillus leptothrix buccalis* of the teeth, that if these are taken directly from the teeth and put in a small drop of violet ink, and a cover glass placed over them, their power to travel will be evident. They move along in a kind of scintillating way, and change their position moderately fast while being observed, so that there is no need of mistaking a bacterial movement for what is known as the Brownian movement of powdered or finely divided inert or mineral particles. The bacterial movement has a distinct and peculiar character. The bacterial form alluded to as traversing the surface of the little *Amphora* was evidently under the restraining influence of a power lodged in the external covering of the *Amphora*. I did not, however, follow it until it freed itself from the *Amphora*. I may remark that this closes an interesting variety of experimental and ocular evidence bearing on the character of motion in the diatom, and also of its protoplasmic surface.

Resuming the thread of my study of the diatoms in the bottle of material from Whistler, Ala., late in the evening of the fifth day of my experimental studies, giving the final examination to the condition of the diatoms at the spot admitting daylight, I was surprised to find that during the interval since I had last examined it exactly fifty desmids had come up and fixed themselves in the illuminated area of one-quarter inch diameter. These were all of one species—*Micrasterias rotata*. The diatoms still had life. But on the next morning—the sixth day—I found that all of the desmids had dropped back into the sediment and were no longer visible, and that the diatoms were all dead and glued to the sides of the bottle by what I took to be colonies of bacteria or some fungoid matter. A new class of life had usurped the territory in continuing the struggle for existence. Collaterally with the living Whistler diatoms, I studied occasionally the bottle containing the Mobile Bay brackish-water diatoms, and I incidentally observed that the rhizopod, *Arcella vulgaris*, was quite common on the sides of the bottle. From the same source I studied the movement of the living pseudopodia of *Difflugia pyriformis*. I was previously familiar with *Amœba proteus*,

but what struck me with most interest during a portion of the time was the presence of beautiful vorticellæ in the sediment at the bottom angles of the bottle. Above the sediment there appeared to be a silvery cloud of monad-like infusoria; and while viewing the vorticellæ with a powerful compound hand lens, the bottle being vertical, I observed that the coronal cilia of the vorticellæ, when expanded and revolving, produced a sort of whirlpool, into which poured a funnel-shaped stream of the minute infusoria. The vorticellæ were attached to débris, and were constantly whirling their cilia and retracting their soft, elongated body. The exuviæ of dying infusoria or bacteria, even from the first day of securing the brackish-water specimens, were rapidly covering everything with a flocculent, ochreous pellicle, which accumulated so rapidly that on the fifth day all the vorticellæ were dead.

The cause of motion in the Diatomaceæ has eluded, so far, a direct and positive solution, and the endosmotic and exosmotic theory seems to be the most favorable hypothesis in the case. The idea of exosmose and endosmose action would occur spontaneously to any one studying the biological functions of the diatom. That there is, and can be, endosmotic action is demonstrated by mounting the dried frustules with thin balsam. The larger *Pinnulariæ* of the Mobile Bay brackish source have the major part of the air within the frustules replaced in a few minutes with the balsam; and this action of displacement of air continues for days after the slide is prepared. This is proved by the so-called canaliculi showing very clearly and distinctly the rib-like markings filled with air bubbles. (That these spaces are not canaliculi, but rather corrugations or flutings, I will endeavor to sustain when I reach the subject of my experiments in charging the markings of the diatoms with coloring matter.) Gradually, after days, there is a full and complete expulsion of all air from the frustules, provided the balsam is thin when first used. If the balsam is quite thick, and dries readily, the air will remain permanently.

In regard to the substances designated as endochrome, chlorophyll, and a substance, derived from the chlorophyllaceous matter of the diatom, known as phycozantina, I have thought it proper to suggest that the contents of diatoms are not identical with the chlorophyll of the desmids or of the leaves of plants, but

are characteristic products of the feeding of the living diatoms among the water plants, or other sources of food supply peculiar to their habitat. I would advance the following, bearing upon the subject, viz.: If the diatoms are expressed from the common green algæ of springs, or slimy confervæ of ditches where the plants are exclusively green, the endochrome is mostly of a dull or bright green, and even emerald green. But the student of the Diatomaceæ is also, almost always, taught to seek for them wherever moist surfaces are covered with a rusty or ochreous color. It is certain that a brown or ochreous color is not indicative of chlorophyll, as the name itself means the "green of a leaf." On the contrary, the contents of the living diatoms derived from brackish mud are mostly brown, or possibly olive brown. While one is contemplating diatoms containing brownish contents, he will also note that the associated vegetable débris in various stages of decay is also brown and matches with the color of the endochrome. So, then, the color of the endochrome is probably a result of the character of the food supply found in the local habitat of the diatom, and it may be a product of morphological assimilation and digestion. On examining certain species of *Surirella* on the Mobile Bay slides, emerald-green stains may be seen at the wedge-shaped end of the frustule, while the balance of the frustule is colorless; but the slides also illustrate brown- or green-colored contents of various shades in extreme profusion.

Having, to my own personal satisfaction, witnessed the indisputable evidence of an intelligence in three representative species of three genera of the Diatomaceæ, and having stated in plain terms the manner in which the proof was adduced, and which is duly capable of verification by any one who will take the trouble to review and corroborate the facts and phases established by my experiments, I will now endeavor to make an expansion of these biological phenomena, to draw attention to the fact that any diatomist, expert or amateur, who sees fit to regard the diatoms as belonging to the protozoa rather than to the unicellular plants, can feel some satisfaction in his own mind, notwithstanding all that is upon record excluding the diatoms from the lowest order of the animal kingdom. This inclination with me has been the outcome of accumulated experience in the study of the

Diatomaceæ, as a purely scientific pursuit or pastime, for the past fifteen years. If the aggregate result of one's efforts in any line of study is of any value, it certainly entitles him to enter the field of generalization, if he finds a reasonable or substantial basis to induce such action.

To within about a year ago I felt satisfied with the commonly conceded position of the Diatomaceæ among the unicellular algæ, and assigned them to the vegetable kingdom in preference to the animal kingdom. Less than a year ago Dr. Arthur Mead Edwards, in a letter to me, propounded the query, "What is a diatom?" and also answered his own question by saying, "I believe that the Diatomaceæ are the Protista." Through an impolitic impulse I replied that it would scarcely be possible to admit that the diatoms were other than "unicellular plants." When, in order to substantiate his conception of their animal characters, he announced in a microscopical journal that he had actually seen the animal occupant of a frustule of *Coletonema eximium* leave and re-enter its shell on several occasions, I wrote him that the species of that name were so small that it would seem hopeless to take that view of one of the smallest among the genus *Pleurosigma*. When we mention the name of this eminent physician, who has devoted forty years of his life to the study of the Diatomaceæ, and who might justly be styled the Nestor of American diatomists, he must be credited with valid reasons for refusing to accept the diatoms as single-celled plants, and for using his abilities in opposition to the continuance of such a view.

I would feel better satisfied to have the station of the Diatomaceæ removed from the domain of doubt which surrounds their position, by irrefragable proof. I would be more contented in realizing that this special class of animated matter was ranged with animal life rather than with plant life. It would tone down and remove from the realm of triviality the enthusiasm of those whose mind has become captivated with the beauty and mystery attached by the Creator to this mystical unit of the universe. If genius could demonstrate beyond cavil the animal nature of the Diatomaceæ, then one would find the objects of his favorite study placed a scale higher than the simple Amœba and in near relation to the beautiful Radiolaria. Who will undertake to explain why the Diatomaceæ so strongly appeal to intellectual

minds? Upon what common grounds of interest have clergymen of all denominations, soldiers, physicians of the cultured races, and many others who were gifted with the naturalistic instinct, been incited to connect their names and fame with a perpetuation of the study of this department of invisible nature, if not through that natural bent which impels the intellectual faculty in certain individuals to an eternal expansion of the philosophical spirit or the conquest of abstraction over matter, space, and time?

Passing to the staining of living diatoms, I will refer to some results accomplished by a few experiments. Having already tried the diatoms derived from a fresh-water spring, I thought proper to extend the process to some fossil fresh-water deposits, on account of their richness and the large size of the contained species. I selected for trial an ounce or two of the fossil fresh-water deposit, discovered by myself two years ago, occurring at Montgomery, Ala., being the most conspicuous deposit of fresh-water forms found in the Southern States.

This deposit contains the largest and most beautiful variety of *Pinnularia nobilis*, whose form was not yet known up to the date of publication of Rev. Francis Wolle's "Diatomaceæ of North America," and, therefore, is not shown in that volume. While employed as draughtsman of the machine shops of the Mobile & Ohio Railroad Company at Whistler, Ala., five miles distant from Mobile, I daily made an extensive use of chemicals in preparing paper for the "blue copying process." I was prompted to use the bath of this process for staining the diatoms. The proportions are these: To an ounce each of red ferriprussiate of potassium and ferrocitrate of ammonia add four ounces of water. The two ounces of diatomaceous earth were boiled in a strong soap solution for an hour or more. Then the boiled diatoms were washed in repeated changes of water to remove objectionable débris and traces of alkali—as the alkalies discharge the blue color of the stain. The diatoms were then freed of water, and decanted on a piece of common blotting paper to remove the remaining water. In this state they were transferred to the "blue process" liquid. The material, in small quantities, was poured on common china plates, and constantly moved about until the liquid and diatoms were spread as a thin layer over the whole surface of the plates, and then exposed to the direct rays

of the bright sunlight for a quarter of an hour or longer. When the rays of the sun had acted sufficiently upon and had thoroughly dried the diatoms, the next step was to recover them by washing the material in pure water and collecting the residuum together again. The experiment proved successful, and the diatoms were seen to be duly stained a beautiful light shade of blue.

I next mounted a slide in balsam and viewed it under the microscope, and was well pleased with the result. The internal corrugations held the stain, differentiating the various markings in a moderately satisfactory manner, and gave the frustules a far better appearance than when unstained. But, not being fully satisfied with the effects of the blue stain, it occurred to me to restain a portion of the material already stained blue. Before having accomplished the blue staining I feared that it would be a failure, and thought to substitute aniline violet for the blue liquid. Taking a pipette, I deposited a quantity of aniline into the blue liquid containing the diatoms, when I observed that the liquids would not mix, but the aniline at once gathered in round drops. Failing in this, I drew off all the blue staining fluid from the diatoms and removed the moisture by decanting again on blotting paper. I next put the diatomaceous mass into pure aniline, and allowed it to be immersed for about five minutes or more. I then removed the excess of aniline dye, and washed the diatoms in repeated changes of pure water until no more stain came off in the water. I then dried the stained material and mounted a slide in balsam. When I submitted the violet-stained diatom slide to microscopic inspection I was pleased at my success, as there was in many frustules a perfect differentiation of all markings of every character; the punctate striæ of *Cymbella*, the pinnulæ of all the *Pinnulariæ*, and the ribs of *Surirella*, were, in many cases, so perfect that every individual rib could be easily counted, the markings called canaliculi, or costæ, having the appearance of a dark, short line with distinct semicircular ends, each perfectly differentiated from its neighboring rib by a delicate, clear line of silex showing no stain; nor was the median smooth surface, divided by the raphe, stained, but the lines of the raphe and its terminal dots were filled with color.

I offer this as my view of the staining: The internal chemi-

cal deposit of the blue stain had thrown down or coagulated the aniline wherever the blue stain had taken effect. Otherwise, where there were no markings visible on the frustules, as on the smooth median surface divided by the lines of the raphe, there was no stain worth noticing. The raphe was in many cases well differentiated, as well as the two central nodular and two terminal dots of the larger *Pinnulariæ*. These two stained slides were the only ones made to test the possibilities and advantages to be derived from staining. As they have given admirable results, it adds another kind of interest in the study of diatoms. Had the material in the slides containing *Amphiprora ornata* been stained either blue or violet, the *Amphiprora* therein could have been readily located on the slides, but in the undyed state they are extremely hyaline and somewhat difficult to locate in balsam mounts under high powers.

The two stained slides were prepared for the series illustrating these notes. In connection with these two slides it may be noted that there is little affinity on the superficial surface of the fossil diatoms for the dye, but the external surface of living diatoms, after drying and mounting, indicates that such surfaces absorb and retain a perceptible amount of dye, which fact suggests that the external layer of protoplasm must have retained it. On an examination of the frustules in the slide stained by the compound process, it will be noted that there is an indication of coagula of the dye adherent to the frustules, while this appearance is entirely wanting in the Whistler fresh-water living diatoms as stained with aniline alone, and in the blue-stained fossil diatoms from Montgomery, Ala.

If my language has been clear, it will be understood that the salient feature of this article is that the diatom is endowed (possibly all diatoms) with two non-interfering motions, qualities indicative of life—namely, the direct and retrograde, which is the generally known and universally acknowledged motion of the whole frustule, single, double, or quadruple, and also the subjective motility of the exoplasm or protoplasmic covering. The principal characteristics of this latter motion have already been given. This claim is, however, not advanced in the case of the discoidal forms, found adherent by countless thousands to marine algæ and the leaves of *Valisneria*, such as *Arachnoidiscus*,

Actinocyclus, *Coscinodiscus*, and *Biddulphia lævis*, which appear to pass their life cycle attached to water plants. But we also know that millions of the travelling frustules are removed from water plants which, when dried, exhibit the frustules in illimitable numbers, as may readily be determined from the mass of moss-like water plants sent herewith to the Society for distribution to such members as may desire to study them in the dry state.

Now, I would suggest that the character of the subjective motion of the protoplasm of the diatom possibly has its homologue in the cilia, pseudopodia, and other admitted protoplasmic appendages of the true Infusoria, and the Rhizopoda, and, in fact, the Protozoa generally; that is to say, in a contractile and extensile power common to the lowest forms of microscopic animal life. Since the activity of the protoplasmic sheath of the *Amphiprora ornata* is now clearly pointed out, it is within the range of verification by the simplest means. One is certain of witnessing a phenomenon that has for many years been of mysterious interest to observers. But there are two kinds of protoplasm, that of plants and that of animals. And the simplest in structure of the animal protoplasms is that associated with the Rhizopoda, which, barring the nucleus, are structureless, gelatinous masses, having an inherent extensile and retractile power, and presenting various modifications of outline. When employed in seeking their food, then their characteristics are best shown and appreciated.

Amœba proteus offers us protoplasm in one of its simplest conditions, that is, where it is devoid of the power of secreting a mineral covering, or even the rudiments of an internal skeleton. From this simple stage protoplasm passes through rising grades of complexity, ending in its power sometimes to secrete a chitinous covering, and sometimes a silicious shell or a shell built up of grains of silex. There is also the simple, structureless protoplasm of the Foraminifera, which is endowed with the power of secreting a shell from calcareous sources, and that of the sponge, which exercises the power of assimilating the molecules of carbonate of calcium or silica disseminated in the fluids of its habitat.

To further expand the relation between animal protoplasm and its peculiar power to secrete silica, I will offer my illustrations

from the domain of the Protozoa. I have consulted as many sources of information as the limited literary resources of my surroundings would admit.

First of all, possessing a copy of Joseph Leidy's "Rhizopods of North America," I consulted that for a portion of my data. In the said monograph is a general account of the classification of the Protozoa and their characteristics, as adapted from the greaf work of Prof. Haeckel. In this I find that, of the true Rhizopoda alone, the following species are characterized as having a protoplasm capable of secreting silicious shells, skeletal coverings, or external appendages—viz., *Euglypha alveolata* and *Euglypha olex; Clathuralina elegans; Acanthocystis* (minute silicious spicules); *Challengeria* (single-celled silicious organisms); *Acanthometrina* (having its spicules arranged in geometrical patterns, such as might be developed in a space of three dimensions, or on the surface of a sphere, and, owing to their extreme delicacy, collapsing or falling apart on drying and handling, and which were apparently only found in the material dredged by the *Challenger*); and also the *Thallasicola*, together with the numerous genera of the Radiolaria.

In connection with these I would refer to the fact that the peculiar open-meshed and stellate silicious skeletons known as *Dictyocha*, hitherto classed with the diatoms, likewise the forms called *Eucampia*, are stated in Wolle's "Diatomaceæ of North America" to be no longer regarded as diatoms, but are excluded therefrom. This dictum would relegate them to the Protozoa. But they are nearly always present in recent as well as fossil diatomaceous earths, as I have put upon record in the JOURNAL of the Society in some remarks upon a small *Navicula didyma* overlapping a *Dictyocha fibula* in the body of a *Coscinodiscus* from the Tampa fossil earth slide, filed with and donated to the Society. What expert diatomist will undertake to clear up the puzzle presented by the fifty or more discoidal forms on the same selected slide, exhibiting, either upon or through the internal structure of the diatom, hundreds of minute diatoms of many distinct species held therein? How did they get there, and why was the selection limited exclusively to the minutest of forms? Has any one, up to the noting of this peculiar characteristic of the discs of the Tampa marine fossil earth, made any observation of a similar con-

dition in the fossil deposits of any other known region of the globe? Notice also the power of the Foraminifera to secrete calcareous shells, and of the Spongidæ to secrete calcareous spicules, and we can infer that the animal protoplasm of the Protozoa has the power to elaborate out of their surrounding fluids the necessary shields or frames best adapted to their vicissitudes.

Against all of these positive and convincing data we can contrast nothing of an analogous kind in plant life. It would be useless to refer to the power of certain plants that flourish in ditches and marshes, and in tropical and semi-tropical regions, as the *Equisetaceæ*, or the canes, bamboos, and cereals, whose cuticular surface is a layer of vegetable silica. I believe that there is not any analogy between the power of the protoplasm of the Diatomaceæ to assimilate oxide of silicon as an integral part of its life, and the power of the plants named above to secrete whatever silica there may be in their woody structure; while there is abundant evidence of the animal protoplasm having in an eminent degree, and almost exclusively so, the power to appropriate from fresh or salt water the requisite silica needed in its life cycle.

But what has already been adduced does not reach the inferential bounds of the subject. Convictions often arise from fortuitous sources to round up a final conclusion. And as the diatomist accumulates fresh experiences year by year, he may group his facts in aiding him to some final conclusion or to reinforce some special view.

It is at this stage of the inquiry that the question comes up, Why is it that in nearly every known marine fossil diatomaceous deposit the silicious skeletons of the Diatomaceæ form the major part of the deposit, with few exceptions? The main exception is where the proportion of the diatoms in the deposit is less than the other fossil organic remains derived from the recognized rhizopods. What construction and interpretation are we justified in putting upon the fact that when we analyze any given fossil marine deposit we invariably find the following derivatives of the Rhizopods, viz., silicious Polycystinæ, or more properly Radiolaria, silicious sponge spicules, and silicious Diatomaceæ, together with calcareous foraminifera, invariably, or at least with few exceptions, associated in deposits of extraordinary thickness? Of two of these typical deposits I can justly claim that, at the

date of writing these notes, I am more familiar with two marine fossil deposits, discovered by myself, than any one else who has made the study of the diatoms a specialty. In one of these the Polycystinæ predominate above the Diatomaceæ, sponge spicules, and Foraminifera. This is the St. Stephens, Ala., eocene deposit, of which this Society possesses selected slides. Yet the diatoms are very abundant therein, and of many species. The other is the marine fossil deposit existing in the Florida phosphate rock area around Tampa, Fla., wherein the Diatomaceæ predominate above the Polycystinæ and silicious sponge spicules, and where calcareous Foraminifera seem to be entirely absent. The egg-shaped or ovoid silicious gemmules of sponges (?) are also very abundant therein. Taking an example right at hand, the world has been supplied with cleaned diatoms from the harbor clays and muds of Mobile Bay, in which are always associated diatoms, a few species of Polycystinæ, silicious sponge spicules, and rhizopods of several species, and more particularly the silicious shell-building ones known as *Difflugia pyriformis*, *Arcella*, and others. The silicious bodies called *Dictyocha* also abound, and the marine Foraminifera which secrete calcareous or chitinous shells. The mineralized calcareous cementstein of Sendai, Japan, and of the islands of Mor and Fur, situated off the northern coast line of Europe, when dissolved in acid, yield masses of Diatomaceæ, sponge spicules, and Polycystinæ, the diatom in the several cases predominating. The fossil diatomaceous clays of the Atlantic seaboard, from Southern New Jersey to Charleston, S. C., at Richmond and other points, always yield a small proportion of Polycystinæ in combination with a tenfold percentage of the Diatomaceæ. The fossil deposits of the Californian coast line yield diatoms in combination with Polycystinæ and sponge spicules, and so on *ad infinitum*.

Passing from the fossil marine deposits which I have put upon record, I will mention two extensive and rich deposits of freshwater origin. First, the lacustrine fossil deposit at Montgomery, Ala., where billions of sponge spicules are associated with a stratum of diatom frustules over twenty feet in thickness and of extraordinary extension. Second, the marine marsh fluviatile deposit found by myself a year or so ago about a mile north of Mobile, on the western bank of Mobile River, which deposit is

characterized by the extraordinary richness of its diatoms, silicious sponge spicules, and billions of silicious rhizopod shells, *Difflugia* and other species.

At this point it might be appropriate to allude to a deposit situated at Montgomery, Ala.—the great artesian basin, about fifty feet in diameter and at least fifteen feet in depth. During a visit to Montgomery I observed that the basin was being cleaned out and that laborers wearing rubber boots were bailing out the ooze that had accumulated at the bottom, which ooze was at that time about eighteen inches deep and of about the consistence of gruel. Desiring to ascertain whether the ooze was a diatom ooze, I secured a quantity of the material and sent it to Mr. C. L. Peticolas, who sent me back beautiful slides of a pure gathering of *Epethemia gibba*. He remarked that it was the prettiest gathering he had ever seen of that species, and likewise the hardest to clean. Associated with the *Epethemia gibba* were a few species of smaller diatoms. This basin has been a feature of Montgomery, Ala., for over fifty years, and it is a remarkable fact that the basin held but one conspicuous species of diatoms through so many years.

As a last resort to defend the thesis that the Diatomaceæ ought to be regarded as belonging among the lower orders of animal life rather than among plant life, we can bring to our aid the established rules of the logician and of the mathematician ; the former granting the use of the syllogism, and the latter that of the "theory of probabilities," either of which I believe would force the solution of the question in favor of an animal status. The fact that the earliest algologists had classed certain genera of the filamentous diatomaceous groups among the Confervoideæ, such as *Melosira*, *Schizonema*, *Homeocladia*, *Mastogloia*, etc., on account of their algaceous habit, does not necessarily compel those to fall into line with their views who choose to regard all diatoms having a distinctive motive power and a motile protoplasmic sheath as belonging to the Protozoa.

Besides Leidy's excellent work, "Rhizopods of North America," I have consulted the able articles of various specialists in well-known encyclopædias, and I am under especial obligations to the paper of the eminent diatomist, Count-Abate Francesco Castracane, entitled "Generalita su le Diatomee" (1884).

I have also consulted the article by Prof. H. L. Osborn, entitled "The Protozoa—a Phyllum of the Animal Kingdom considered Biologically" (*American Monthly Microscopical Journal*, October, 1892), and the presidential address by Mr. Charles F. Cox, published in the JOURNAL of this Society, January, 1892. I have not had access to the recently published work of Messrs. Frederick W. Mills and Julien Deby, "An Introduction to the Study of the Diatomaceæ" (London and Washington, 1893), so that to this fact must be attributed any lack of acquaintance with the theories which may have been lately proposed.

Before closing I fain would refer to the use made by certain animals of the Diatomaceæ as a part of their food supply, with the view of determining whether the nourishment adapted to carnivorous animals is made up of microscopic plant protoplasm, either of what is called the ectosarc or endosarc of the Diatomaceæ. The most striking example within my own experience is that source of the Diatomaceæ derived from the gizzard or craw-like organ of the mullet of the Gulf bays From such gullets I have secured hundreds of pear-shaped pellets which were literally masses of pure diatoms, and of which I sent many in exchanges, both to foreign countries and also to Mr. C. L. Peticolas, of Richmond, Va., who returned to me at times beautiful preparations of the same. I have never found anything else but diatoms and sand grains in these fish gizzards, so this, as far as my experience goes, was the only food supply preyed upon by the mullet. I have also demonstrated that the desiccated excrementitious matter left by sea gulls on clusters of pilings in Mobile Bay has been a rich source of marine diatoms, after the undigested particles of fish bones, etc., are dissolved away with acid. As the diet of the sea gulls is principally fish, we can readily account for the presence of diatoms in such a recent source as the living sea gull. The stomach of the oyster sometimes yields diatoms, but the green masses found in the stomach are preferably marine algæ. The digestive tracts of the sea cucumbers—Holuthuriæ—have been justly celebrated for yielding immense numbers of marine diatoms. The trepang of the China Sea (which is dried abroad and sold in Mott street, New York, as a Chinese delicacy) is a sun-dried sea cucumber. From several sources we learn that in the Arctic and Antarctic regions

the Diatomaceæ float on the surface of the seas as a dense foamy sheet and are the sole food of some kinds of fish. The Abbé Castracane, already referred to, has written a special paper on the presence of the Diatomaceæ as the sole and exclusive food of *Echinus* and Echinodermata and Holothuriæ, dredged by the *Challenger* from depths of 2,000 and 5,740 metres. His object was to prove, contrary to common belief at that period, that plant life vegetated at a depth where the rays of the sun never penetrated. The fact of his finding rich masses of *Synedra thallassiotrix* Cleve. and *Coscinodiscus* in the Holothuriæ and Echini taken from these depths confirmed his belief. As the Abbé was a firm believer in the plant nature of the Diatomaceæ, he could not well do otherwise than regard this kind of food as plant life. He proved that the diatoms passed their life cycle at the bottom of the ocean, at 5.740 metres, on the feeding ground of the Echini and Holothuriæ, as the endochrome had not been removed by the digestive juices of the Echini or Holothuriæ after their removal by the dredge from their habitat at the bottom of the ocean, thus drawing another illustration of the use of the Diatomaceæ as a food supply.

I would note that at least four of the slides prepared from Mobile Bay brackish-water material, and sent herewith, show a number of rhizopods, *Euglypha alveolata*, within whose transparent and glass-like shells may be seen several varieties of very minute diatoms—viz., *Cocconeis pediculus* and *Naviculæ*. Also in a more pronounced manner, in the beautiful plates of Leidy's "Rhizopods of North America," various amœbæ are depicted at the moment of enveloping within their fluent protoplasmic layers large *Pinnulariæ* and other diatoms. And I have put upon record with this Society a selected slide of *Difflugia pyriformis* and other species, in which minute diatoms are seen to form a part of the solid shell covering the soft pseudopodial parts of the animal protoplasm when in its living state.

In the slides referred to above a pair of shells of *Euglypha alveolata* are mounted, showing the mouths of the shells in contact, or in the position usually regarded as that of conjugation. In the same slides will be noted an extraneous class of minute animals found in Mobile Bay—viz., minute shrimp, whose chitinous

cases have been turned a light hue of pink through immersion in balsam.

Before quitting the rhizopods I would make one more reference to an interesting feature that will have its application in summing up the consequences of these notes. I quote certain paragraphs in the article by Prof. Osborn, noticed above: "In its chemical nature the covering of *Hyalosphenia* is interesting, being *albuminoid* and less unlike the chemical nature of compounds in the protoplasm than are the skeletons of lime or silica found in *Ratalia* (foraminifera) *actinospherium* and many other specialized rhizopods. *It is, therefore, a less specialized act of the secretory power to produce a chitinous than a calcareous or silicious skeleton.*" And again: "*Liberkuhnia* is a naked body of rather definite outline, with one end prolonged into pseudopodia. The pseudopodia are never strictly radial, but are branching, the branches leading out into finer and finer divisions which often anastomose or join together. *The food is caught upon the network of pseudopodia and digested there.*" Or, in other words, we may put this interpretation on the concluding sentence, that an infinitesimal thread of protoplasm has a digestive, and as a consequence an assimilative, power. Can we not then inquire whether the living and moving protoplasmic layer of *Amphiprora ornata* has not an identical power, and is it not performing this digestive and assimilative function when it carries from point to point on its perimeter such particles as a motionless rotifer or a bacterium?

From the preceding restricted reference to animal life dependent on the Diatomaceæ, we are led to inquire whether an animal protoplasm would not be better associated with the idea of the sustenance of carnivorous animals, rather than that they should seek the sustenance of a purely plant protoplasm to build up and sustain their own changes of growth or waste.

This problem of the true nature of the sarcode of the Diatomaceæ is now respectfully submitted to those observers who care to take the pains to strive for a solution through observation, until no doubt shall remain as to what it is, whether absolutely plant or absolutely animal in its nature.

I would offer a few words explanatory of the contents of the six slides exhibiting the diatoms from the edge of Mobile Bay shore. They are prepared in duplicate, two of a kind, to show the

smallest species, the intermediate, and the largest discs. And the following genera are represented by from two to ten or more species each: *Achnanthes*, *Amphora*, *Amphiprora*, *Actinocyclus*, *Actinoptychus*, *Cocconeis*, *Cyclotella*, *Coscinodiscus*, *Campylodiscus*, *Cymbella*, *Epethemia*, *Eunotia*, *Gomphonema*, *Melosira*, *Nitzschia*, *Navicula*, *Odontidium*, *Pleurosigma*, *Steuroneis*, *Surirella*, *Synedra*, *Terpsinoe*, *Tabellaria*, the Naviculæ, however, being in the majority. In the observations of the living diatoms detailed herein I used a Zeiss D lens and at a magnification of about 600 diameters.

PROCEEDINGS.

Meeting of April 7th, 1893.

The President, Mr. Charles S. Shultz, in the chair.

Twelve persons present.

Mr. Noah Palmer was elected a Resident Member of the Society.

Dr. Samuel Lockwood, who was expected to deliver the address announced on the programme, was by illness prevented from attendance. An informal session was held.

Annual Exhibition, April 19th, 1893.

The Fourteenth Annual Exhibition of the Society was held at the American Museum of Natural History, Central Park, New York City, on the evening of April 19th, 1893.

Objects and apparatus, as noted in the programme below, were displayed in the large hall on the first floor of the Museum. At 9 o'clock Rev. E. C. Bolles, D.D., in the Lecture Room adjoining, gave an explanation of the projection of numerous microscopic objects on the screen.

PROGRAMME.

1. Water Wood-louse, *Asellus aquaticus*, showing the circulation of the colorless blood: by H. C. Bennett.

2. Section of Human Scalp, showing hair follicles, sebaceous glands, and ducts: by H. C. Bennett.

3. Transverse Section of a Cat's Tongue: by Wm. Wales.

4. Section of Soap Bark, *Quillaya saponaria*, showing long prismatic crystals: by G. H. Blake.

5. Sulphate of Copper, shown by polarized light: by N. Palmer.

6. Coal. Vascular Cylinder of a Young Stigmaria: by F. W. Leggett.

7. Head of Tape-worm, *Tænia solium*, showing the Rostellum and Suckers, with drawings of the same. Also specimens of the Head in alcohol: by L. Schöney.

8. Butterfly Scales and Diatoms arranged in the form of a Vase of Flowers: by G. S. Woolman.

9. Transverse Section of the Head of a Moth, *Utetheisa bella*: by L. Riederer.

10. Longitudinal Section of the Antenna of a Wasp, *Vespa maculata*: by L. Riederer.

11. Transverse Section of the Head of a Fish, *Atherina*: by L. Riederer.

12. Transverse Section of the Body of a Fish, *Atherina*: by L. Riederer.

13. Microtome, manufactured by Aug. Becker, Göttingen, Germany: by L. Riederer.

14. Selection of Serial Sections: by L. Riederer.

15. Young of Marine Crustaceans: by E. J. Riederer.

16–18. Bacilli of Asiatic Cholera: by J. A. Gottlieb.

16. From a Culture in Bouillon, × 1,550.

17. From a Gelatin Culture, × 1,200.

18. Cultures in Nutrient Gelatin in Various Stages of Development.

19. Human Blood, × 590: by J. A. Gottlieb.

20. Blood of Seventeen-day Embryo Chick, × 480: by J. A. Gottlieb.

21. Frog's Blood (stained), × 330: by J. A. Gottlieb.

22. The Leitz Photomicrographic Apparatus: by J. A. Gottlieb.

23. Projection Apparatus, after Edinger: by J. A. Gottlieb.

24. Large Dissecting Microscope with Abbe's Camera Lucida: by J. A. Gottlieb.

25. Six Sections of Building Stones, shown on Automatic Re-

volving Stage by polarized light. Also specimens of the stones from which the sections were cut : by J. WALKER.

26. Polycystina: by J. WALKER.

27. Section of the Human Tongue : by C. S. SHULTZ.

28. Eggs of Various Insects, arranged : by C. S. SHULTZ.

29. Type Slide of Diatoms, arranged by D. B. Ward : by A. M. EDWARDS.

30. Circulation of Protoplasm (Cyclosis) in Nitella : by M. M. LE BRUN.

31. Young Codfish, one to three days old : by H. W. CALEF.

32. Transverse Section of the Leaf of the East India Rubber Tree, *Ficus elastica*, showing fibres, ducts, stomata, and cell tissue : by FREDERICK KATO.

33–36. Living and Pictorial Illustrations of Several of the Lower Forms of Animal and Vegetable Life : by STEPHEN HELM.

37. Pond Life : by A. D. BALEN.

38. Cinchonidine, shown by polarized light: by MISS M. V. WORSTELL.

39. Circulation of Protoplasm (Cyclosis) in Chara : by J. D. HYATT.

40. Ciliary Motion on the Gills of the Mussel : by J. D. HYATT.

41. Tongue of a Cricket : by W. D. MACDONALD.

42, 43. Pond Life : by H. C. WELLS.

44. The Curious Aquatic Insect, *Rheumatobates Rileyi* Bergroth, captured at Flatbush, L. I.; named by E. Bergroth, M.D., Tammerfors, Finland; and until recently the only reported specimen in the world: by J. L. ZABRISKIE.

45. Arranged Group of Diatoms, illuminated by parabola : by C. F. COX.

46. Crystals of Sugar, shown by polarized light : by C. F. COX.

47. Leaf of Deutzia scabra, showing stellate hairs : by W. E. DAMON.

48. Spines of Echinus: by H. G. PIFFARD.

49. Circulation of Blood in Tail of Tadpole: by F. W. DEVOE.

50. Circulation of Protoplasm in Vallisneria spiralis: by F. W. DEVOE.

51. File-tongue (*Odontophore*) of the New Jersey Conch, *Sycotypus canaliculatus*, with the shell: by SAMUEL LOCKWOOD.

52. File-tongue (*Odontophore*) of California Trochus, *Calliostoma canaliculatum*, with the shell: by SAMUEL LOCKWOOD.

53. File-tongue (*Odontophore*) of Patella, or Limpet Shell, *Acmæa testudinalis*, New England coast, with the shell: by SAMUEL LOCKWOOD.

54. Photomicrographic Apparatus: by F. D. SKEEL.

55–59. Star-fish and Sea-urchins, illustrated by living forms, microscopic specimens, and drawings: by G. W. KOSMAK.

60–66. Etchings of Steel Rails, showing Structure: by P. H. DUDLEY.

60. A .60% carbon Rail, with broad, shallow head. Dense structure.
61. A .45% carbon Rail, with deep head. Porous structure.
62. A good wearing Rail, made in 1863.
63. A rapid wearing Rail, made in 1880.
64. Nickel Armor Plate.
65. Specimens of Tests of Armor Plate, Ordnance, and Rail Steel.
66. Photographs of Drop Tests of a .60% Carbon Rail, etc.

67, 68. Sections of Silicified Wood, *Araucaria Briggsii*, from Arizona: by T. B. BRIGGS.

67. Transverse Section.
68. Radial Section.

69. Section of Wood, *Araucaria excelsa*, from Norfolk Island: by T. B. BRIGGS.

70. Platino-cyanide of Yttrium, shown by polarized light: by E. G. LOVE.

71. Seeds of Orthocarpus purpurascens: by E. G. LOVE.

72. Pollen of Mallow, *Malva rotundifolia:* by E. G. LOVE.

73. Foot of Spider: by E. G. LOVE.

74. Photomicrographs: by E. G. Love.

75. Pond Life: by W. C. KERR.

76. A Living Diatom, *Bacillaria paradoxa:* by T. CRAIG.

77. Hydra viridis: by J. C. THOMPSON.

78. Circulation in Frog's Foot: by J. C. THOMPSON.

79. Pond Life: by O. H. WILSON.

80. Circulation of Protoplasm in the Skin of the Onion: by M. DUPUY.

81. Colored Drawings of Microscopic Objects: by M. DUPUY.

82–86. Microphotographs, selected: by S. N. AYRES.

87. Fossil Vegetable Structure in Coal Shale: by GEO. E. ASHBY.

88. Section of Stalactitic Chalcedony, shown by polarized light: by J. W. FRECKELTON.

89. Desmids: by E. J. WRIGHT.

90. Quartz Inclusions in Mica, shown by polarized light: by A. H. EHRMAN.

91. Microphotograph of Niagara Falls: by H. FINCKE.

92. California Gold Sand: by H. FINCKE.

93. Arranged Diatoms: by H. FINCKE.

94. Nitroprusside of Sodium, shown by polarized light: by H. FINCKE.

95. Section of Malacca Cane from Malay Peninsula: by A. WOODWARD.

96. Ash Block containing Living Termites, *Calotermes flavicollis*, taken at the Isthmus of Panama, August, 1890: by J. BEAUMONT.

97. Specimen of Termite Tree Nest, *Termes minimus* Beaumont, with alcoholic specimens of queen, soldiers, and workers: by J. BEAUMONT.

98. Cultivation, Staining, and Mounting of Bacteria: by P. H. LYON.

99. Circulation in the Tail of a Gold-fish: by W. H. MEAD.

100. Tooth of Fossil Fish in Coal: by THE SOCIETY.

MEETING OF APRIL 21ST, 1893.

The President, Mr. Charles S. Shultz, in the chair.

Fourteen persons present.

Dr. Frank Abbott, Jr., was elected a Resident Member of the Society.

On motion the thanks of the Society were tendered Mr. Morris K. Jesup, President of the Board of Trustees, and the Officers of the American Museum of Natural History, for their kindness in granting the use of the Halls of the Museum, and for their generous assistance in the matter of the late Annual Exhibition of the Society.

OBJECTS EXHIBITED.

1. Gas carbon filaments, deposited on the edge of a burner: by E. G. LOVE.

2. Diatoms from the Bay of Bengal: by H. C. BENNETT.

3. Section of Cementstein from Sendai, Japan: by H. C. BENNETT.

4. Living diatoms: by C. S. SHULTZ.

MEETING OF MAY 5TH, 1893.

The President, Mr. Charles S. Shultz, in the chair.

Sixty persons present.

Dr. George M. Sternberg delivered the address announced on the programme, entitled "Bacteria." This address was most admirable for its comprehensiveness and its perspicuity, and was beautifully illustrated by a most remarkable series of lantern projections.

On motion the hearty thanks of the Society were tendered Dr. Sternberg.

MEETING OF MAY 19TH, 1893.

The President, Mr. Charles S. Shultz, in the chair.

Twenty-four persons present.

Dr. Samuel Lockwood addressed the Society on "Some Phenomena in Exuviation by the Reptiles." This address was illustrated by specimens and objects under microscopes, as noted in the programme below, and is published in this volume of the JOURNAL, page 55.

OBJECTS EXHIBITED.

1. Bronze, life-size representations of Snake, Lizard, and Frog.

2. "Scarf" of Anaconda.

3. Skin of the Lizard, *Anolis principalis*, under a $\frac{1}{5}$ objective, showing "the windows."

4. Skin of the Horned Toad, *Phrynosoma cornuta*, under a $\frac{1}{5}$ objective, showing pigment grains.

Exhibits Nos. 1–4, inclusive, were by SAMUEL LOCKWOOD.

5. Photomicrograph, half-tone print, of scale of Podura, *Lepidocyrtis curvicollis*, × 3,000 : by H. G. PIFFARD.

6. Photomicrograph of pygidium of Flea, taken by Dr. Henri Van Heurck, who regards this object as a test, second in value only to the Podura scale : by H. G. PIFFARD.

7. Various Diatoms : by NOAH PALMER.

Some points on the changeability in color of the skin of the Chameleon, in Dr. Lockwood's address, were discussed by Messrs. J. D. Hyatt, L. Riederer, and W. J. Lloyd. Mr. Riederer suggested that the changeableness may be somewhat on the principle of "Newton's rings," since there are two films in the skin of the chameleon.

MEETING OF JUNE 2D, 1893.

The President, Mr. Charles S. Shultz, in the chair.

Twenty-four persons present.

Dr. H. G. Piffard read a paper entitled "An Improvement in the Correction of Lenses for Photomicrography, Photography, and Photoastronomics." This paper was illustrated by many photomicrographs, as cited below.

OBJECTS EXHIBITED.

1. Watson's Van Heurck Stand : by H. G. PIFFARD.

2. *Navicula rhomboides*, under a William Wales $\frac{1}{10}$, made eighteen years ago : by H. G. PIFFARD.

3. The same ; resolution of "beads," with parabola : by H. G. PIFFARD.

4. Podura scale : by H. G. PIFFARD.

5. Photomicrographs : blood of *Amphiuma*, *Echinus* spine, probe platte, histological section, Podura scale, *Amphipleura pellucida*, *Limulus*, copy of a painting, street scene, interior view : by H. G. PIFFARD.

6. *Amphipleura pellucida:* by HENRY C. BENNETT.

7. Probe platte by Möller: by HENRY C. BENNETT.

8. Photomicrographs: *Amphipleura* × 1,500, *Pleurosigma angulatum* × 6,000, section of human eye: by F. D. SKEEL.

9. *Frustula saxonica*, $\frac{1}{10}$ homogeneous immersion lens and vertical illuminator: by CHARLES S. SHULTZ.

MEETING OF JUNE 16TH, 1893.

The Vice-President, Dr. E. G. Love, in the chair.

Dr. F. D. Skeel was elected Secretary *pro tem.*

Surgeon-General George M. Sternberg, U. S. A., was elected an Honorary Member of the Society.

Dr. E. G. Love, chairman of the Committee on Annual Exhibition, reported for the Committee, and the Committee was discharged with thanks.

OBJECTS EXHIBITED.

1. According to previous appointment, the entire collection of "Jackson Slides," recently purchased by the Society, were exhibited in succession.

2. Photomicrographs of *Triceratium favus* × 1,500, and of *Pleurosigma angulatum* × 750 and 6,000: by FRANK D. SKEEL.

The Society adjourned to the first Friday of October, 1893.

PUBLICATIONS RECEIVED.

American Monthly Microscopical Journal: Vol. XIV., Nos. 2—9 (February—September, 1893).

The Microscope: Vol. I., Nos. 2—10 (February—October, 1893).

San Francisco Microscopical Society: Proceedings (April 9—March 1, 1893); Transactions, Part I. (1893).

Bulletin of the Torrey Botanical Club: Vol. XX., Nos. 3—10 (March—October, 1893).

Insect Life: Vol. V., Nos. 4, 5 (April, July, 1893).

Psyche: Vol. VI., Nos. 204—211 (April—November, 1893).

The Observer: Vol. IV., Nos. 1—10 (January—October, 1893).

Proceedings of the Natural Science Association of Staten Island: Index of Vol. II. (November 10, 1888—October 10, 1891); Meetings (March 18—October 14, 1893).

Anthony's Photographic Bulletin: Vol. XXIV., Nos. 5—21 (March 11—November 11, 1893).

School of Mines Quarterly: Vol. XIV., Nos. 2—4 (January—July, 1893).

American Museum of Natural History: Annual Report (1892).

New York Academy of Sciences: Index of Vol. XI. (1892); Transactions, Vol. XII. (1892, 1893).

Proceedings of the American Academy of Arts and Sciences: Vol. XXVII. (1892).

Proceedings of the Boston Society of Natural History: Vol. XXVI., Part I. (November, 1892—May, 1893).

Proceedings of the Academy of Natural Sciences of Philadelphia: 1893, Parts I. and II.

Bulletin of the Museum of Comparative Zoölogy at Harvard College: Vol. XXIV., Nos. 6, 7—Vol. XXV., No. 1 (July—September, 1893).

Journal of the Franklin Institute: Vol. CXXXV., No. 807—Vol. CXXXVI., No. 815 (March—November, 1893).

Transactions of the Massachusetts Horticultural Society: Part II., 1892; Part I., 1893.

Journal of the Elisha Mitchell Scientific Society: Vol. IX., Part II. (1892).

Transactions of the Connecticut Academy of Arts and Sciences: Vol. VIII., Part II.; Vol. IX., Part I. (1893).

Report of the Missouri Botanical Garden (1893).

United States Geological Survey: Eleventh Annual Report, Parts I. and II. (1889—90).

Proceedings of the Rochester Academy of Science: Vol. II., No. 2 (1893).

Bulletin of the Essex Institute: Vol. XXIV., No. 7—Vol. XXV., Nos. 1—6 (July, 1892—June, 1893).

Journal of the Cincinnati Society of Natural History: Vol. XV., No. 3—Vol. XVI., No. 3 (October, 1892—October, 1893).

Cornell University Agricultural Experiment Station, Bulletins: Nos. 50—57 (March—September, 1893).

Bulletin of the Michigan Agricultural Experiment Station: Nos. 90—99 (February—July, 1893).

Bulletin of the Iowa Agricultural Experiment Station: Nos. 20, 21 (1893).

Bulletin of the Alabama Agricultural Experiment Station: Nos. 41—47 (December, 1892—July, 1893).

Bulletin of the Texas Agricultural Experiment Station: No. 26 (March, 1893).

Bulletin of the Division of Entomology, U. S. Department of Agriculture: Nos. 29, 30 (1893).

Colorado Scientific Society: Six pamphlets (1893).

Journal of the Royal Microscopical Society: Parts II.—V. (1893).

International Journal of Microscopy and Natural Science: Vol. III., Nos. 18—20 (April—October, 1893).

Journal of the Quekett Microscopical Club: Vol. V., No. 32 (July, 1893).

Manchester Microscopical Society: Transactions and Report (1892).

The Naturalist: Nos. 212—220 (1893).

Penzance Natural History and Antiquarian Society: Report and Transactions (1893).

Proceedings of the Bristol Naturalists Society: Vol. VII., Part II. (1893).

Canadian Record of Science: Vol. V., Nos. 5—7 (1893).

Geological Survey of Canada: Catalogue of Rocks prepared for Columbian Exposition (1893); Catalogue of Minerals in the Museum (1893).

Transactions of the Canadian Institute: Vol. III., Part 2 (1893).

Historical and Scientific Society of Manitoba: Annual Report (1892); Transactions, No. 44 (January, 1893).

The Ottawa Naturalist: Vol. VI., No. 11—Vol. VII., No. 8 (March—November, 1893).

Nova Scotian Institute of Science: Vol. I., Part II. (1892).

Royal Society of New South Wales: Journal and Proceedings, Vol. XXVI. (1892).

The Victorian Naturalist: Vol. IX., No. 10—Vol. X., No. 5 (February—September, 1893).

Australian Museum: Annual Report (1892); Records, VII., No. 4 (February, 1893).

Actes de la Société Scientifique du Chili: Vol. II., No. 3 (February, 1893).

Revista del Museo de la Plata: Vol. III. (1892).

Brooklyn Medical Journal: Vol. VII., Nos. 4—11 (April—November, 1893).

American Lancet: Vol. XVII., Nos. 3—11 (March—November, 1893).

Indiana Medical Journal: Vol. XI., No. 9—Vol. XII., No. 5 (March—November, 1893).

Le Diatomiste: Vol. I., No. 12—Vol. II., No. 2 (March—September, 1893).

Johns Hopkins University: Studies from the Biological Laboratory, Vol. V., Nos. 2—4 (March—October, 1893); University Circulars, Vol. XII., Nos. 104—107 (March—June, 1893).

National Druggist: Vol. XXII., No. 6—Vol. XXIII., No. 11 (March—November, 1893).

The Mining Review: Vol. XXX., No. 10—Vol. XXXI., No. 19 (March 9—November 9, 1893).

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Annual of the Universal Medical Sciences: Vols. I.—V. (1893).

Universal Medical Journal: Vol. I. (February—October, 1893).

Société Belge de Microscopie: Bulletin, Vol. XIX., Nos. 4—7 (March—May, 1893); Annales, Vol. XVII., No. 1 (1893).

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Feuille des Jeunes Naturalistes: Vol. XXIII., Nos. 269—277 (March—November, 1893).

Société Nationale des Sciences Naturelles de Cherbourg: Mémoires, Vol. XXVIII. (1892).

Société des Sciences Naturelles de la Creuse: Mémoires, Vol. VII. (1892).

Société des Sciences Naturelles de Béziers: Bulletin, Vol. XIV. (1891).

Société d'Etudes Scientifiques d'Angers: Bulletin, Vol. XXI. (1891).

Société les Amis des Sciences et Arts: Bulletin, Vol. III., Nos. 2, 3 (1893).

Naturwissenschaftlicher Verein des Reg.-Bez. Frankfurt-a-Oder: Helios, Vol. X., No. 10—Vol. XI., No. 5 (January—August, 1893); Societatum Litteræ, Vol. VII., Nos. 1—7 (January—July, 1893).

Gesellschaft zur Beförd. der gesammten Naturwissenschaften zu Marburg: Sitzungsberichte (1892).

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L'Académie Royale des Sciences, Stockholm: Transactions, Vol. XIV., No. 3—Vol. XVII., No. 4 (1889—1892).

Société Impériale des Naturalistes de Moscou: Bulletin, 1892, Nos. 3, 4.

Société des Naturalistes, Kiew: Mémoires, Vol. XII., No. 2 (1892).

Naturhistorische Gesellschaft u. Nürnberg: Abhandlungen, Vol. X., No. 1 (1892).

Nassauischer Verein für Naturkunde, Wiesbaden; Jahresbericht (1892).

Sociedad Científica "Antonio Alzate"; Memorias, Vol. VI., No. 7—Vol. VII., No. 2 (1893).

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California Academy of Sciences: Proceedings, Vol. III., Part II. (July, 1893); Occasional Papers, IV. (1893).

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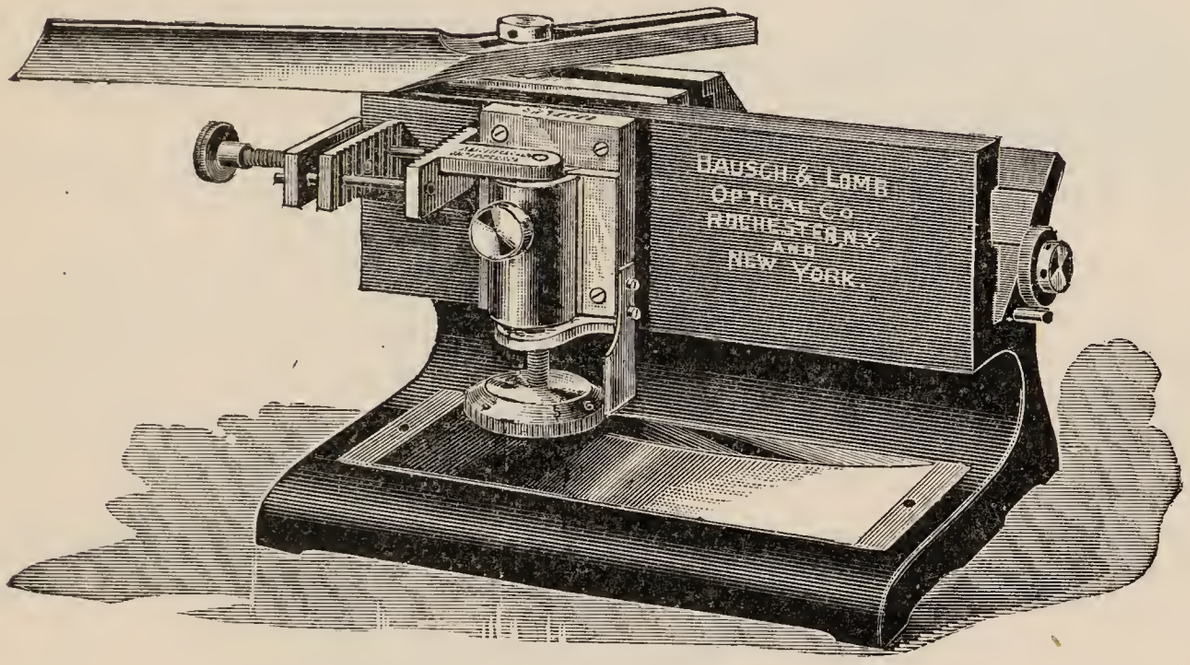

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